ESE Sensors & Detectors Program Overview

Presentation

To

Technology Strategy Team

Office of Earth Science

January 27, 1999

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757.864.6680

ESTO

Earth Science Technology Office

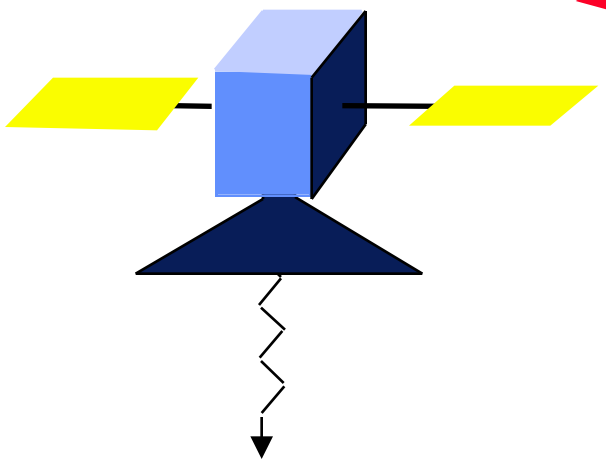
Relationship to Other Programs

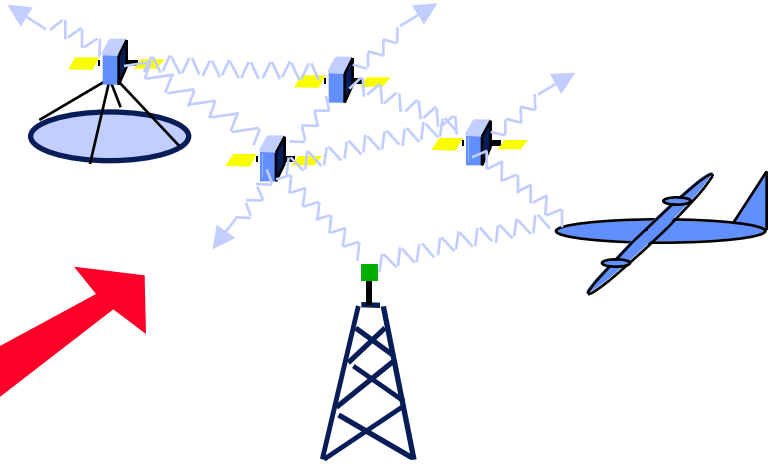
- **Sensor & Detector Technology Program**
  - **Development of "seed corn" core technology**
- Instrument Incubator Program (IIP)
  - Bridges the technology gap
- New Millennium Program (NMP)
  - Provides space validation

Earth Science Enterprise Technology Vision

1997 MTPE Realities

- Focus on Earth system characterization
- Large, expensive instruments & S/C, single-platform deployment
- Labor intensive operations by teams of experts, no onboard autonomy
- Little on-board processing capability
- Expert access to individual data sets

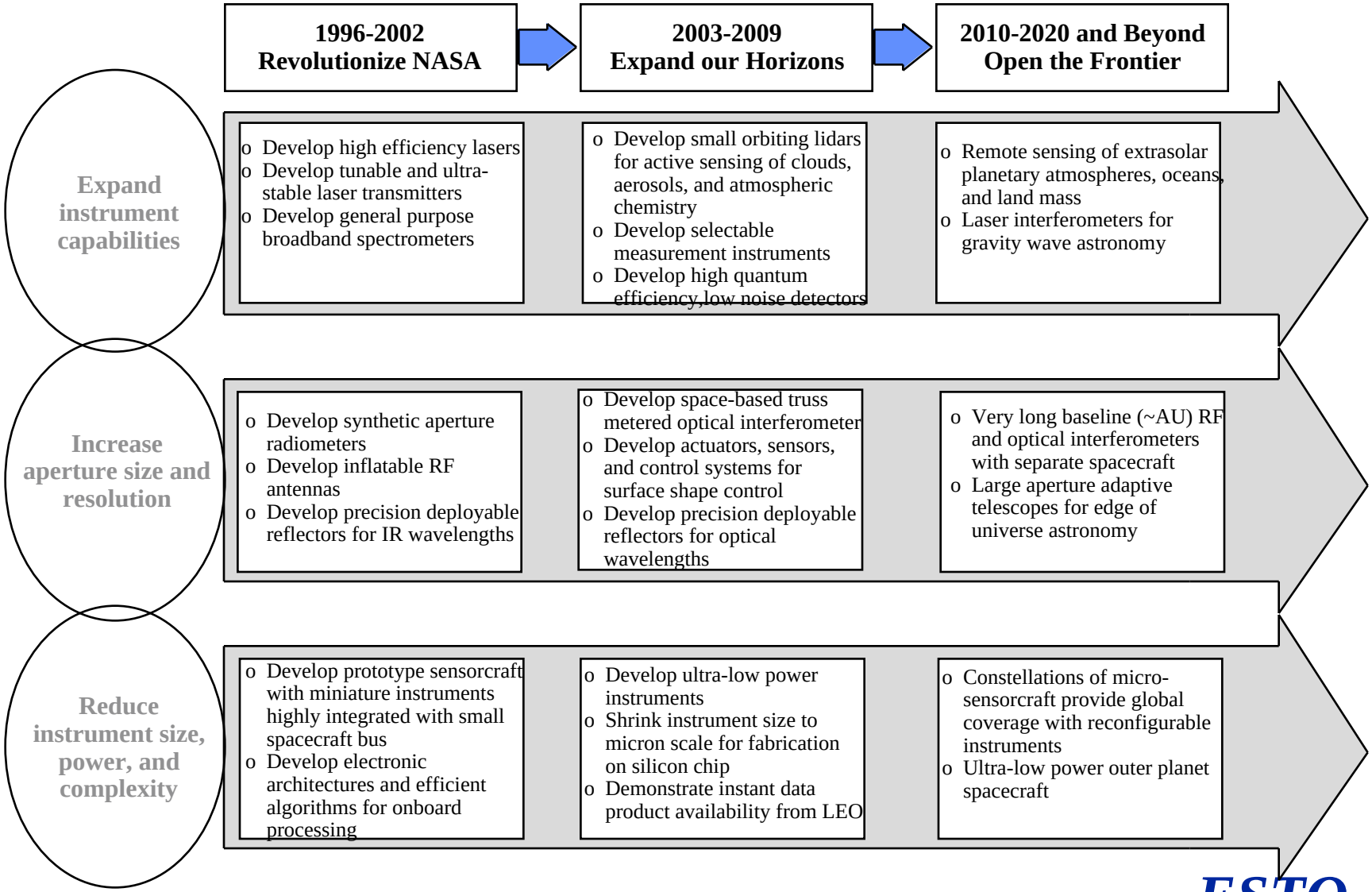




2010-2025 MTPE Implementation Vision

- Focus on Earth system assessment & forecasting
- Low mass/cost active & passive instruments, large deployable apertures
- Space constellations & cooperative multi-platform campaigns
- Image registration, cross calibration & data fusion
- Low mass/cost smart S/C with high-level commanding, low-cost operations
- Autonomous high rate data acquisition, processing, cross/downlink
- User friendly data architecture supportinginfo-mining and data set fusion to support Earth system modelling

INSTRUMENT TECHNOLOGIES ROADMAP



Instruments Technology SOA and Goals

Summary

	State-Of-Art	2020 Goal
Transmitters	Low efficiency lasers (< 5%) Multiple fixed frequencies Single mode operation Low repetition rate Frequency drift	**High efficiency lasers (> 20%)** **Wide frequency tunability** **Multi-mode operation** **High repetition rate** **Ultra-stable oscillators**
Receivers	Narrowband, low throughput filters Monolithic filled apertures Short baseline interferometers (~m) Pre-figured surfaces Alignment sensitive fixed optics	**Tunable, high throughput filters** **Deployable synthetic apertures** **Very long baseline interferometers (~AU)** **Surface shape control** **Adaptive optics**
Detectors	Low quantum efficiency (<35%) High noise, cooled detectors Multi-channel CCDs High power (~W)	**High quantum efficiency (>60%)** **Low noise, room temperature detectors** **Broadband spectrometers (300 nm -15 μm)** **Ultra-low power (~mW)**
Integration	Large spacecraft bus / multiple instr. Special purpose, single measurement instruments Discrete optical components Raw data downlink	**Swarms of micro-sensorcraft** **General purpose, selectable measurement instruments** **Optics integrated with fiber** **Real-time onboard processing**

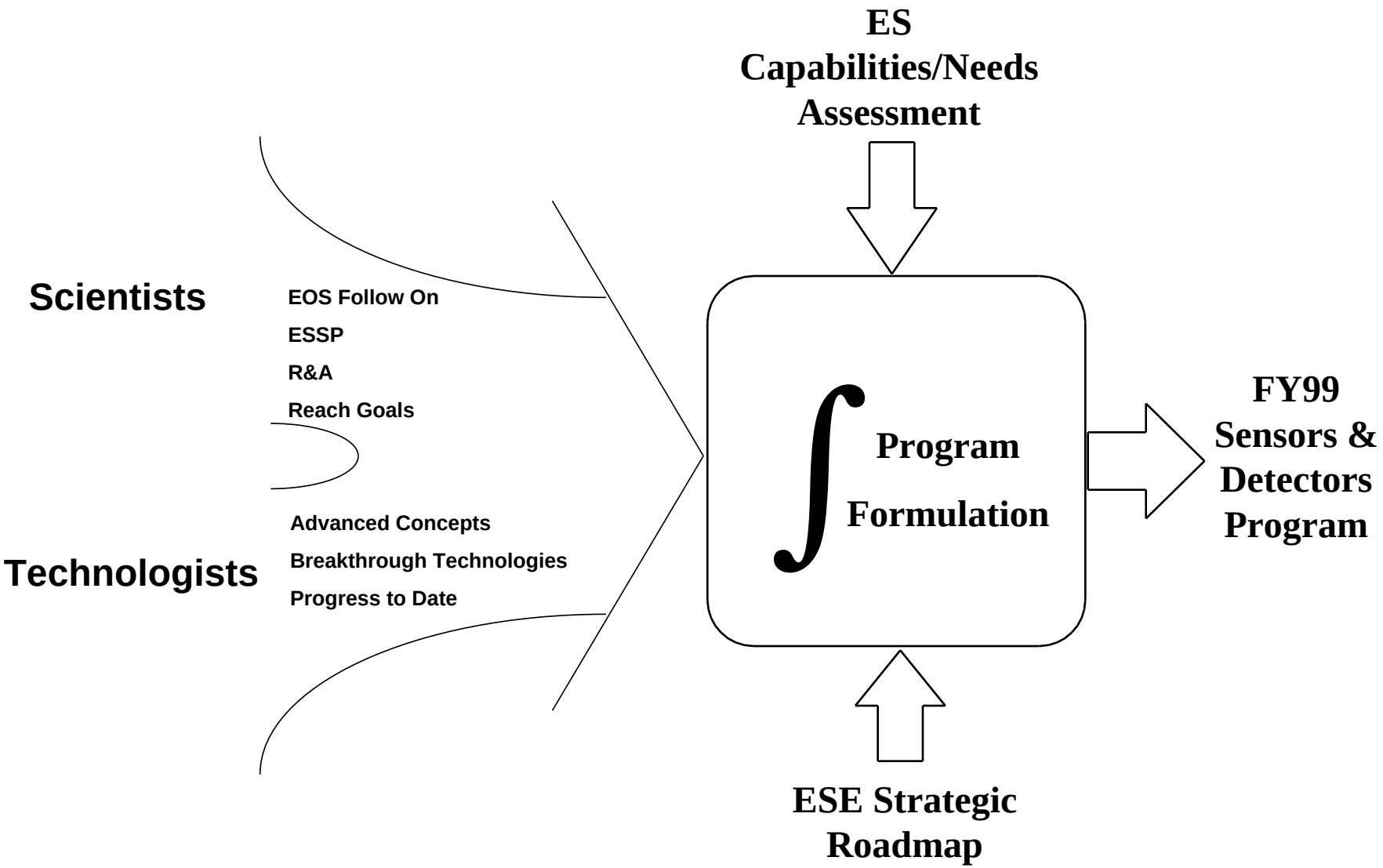
2020 Vision

ES Technology Program Objectives

"Advanced technology is the key to maintaining the pace of scientific discovery. Aggressive infusion of new technology enables smaller, cheaper satellite missions, providing an opportunity for new missions in a constrained budget environments." - ESE Strategic Plan

- Reduce science product life-cycle cost
  - reduce instrument weight, power, volume
    - » e.g., Advanced Fourier Transform Spectrometer
- Enable new Earth System Science measurements
  - develop and validate breakthrough systems and subsystems technologies
    - » e.g., Ozone Differential Absorption Lidar
- Enable new sensor-to-science knowledge information architectures
  - seek information handling efficiency and effectiveness
    - » e.g., GAMS and FTS onboard data processing

FY99 Program Development Process



Capability/Technology Needs Assessment Plan

- Traceability of Technology Development Activities -

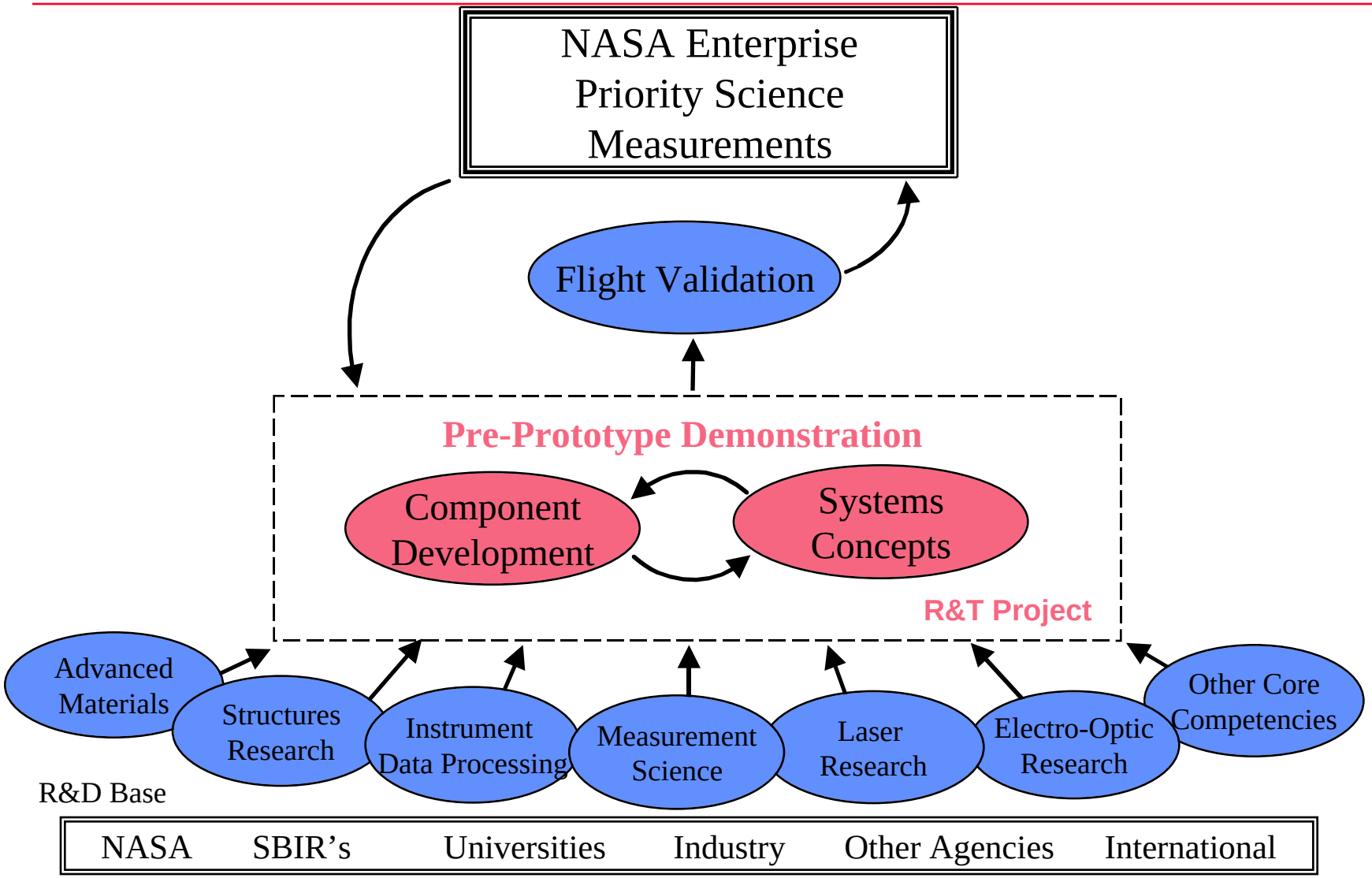
R&T Project	Science Driver	Science Theme	Earth Sys. Quantity
Fourier Transformer Spectrometer (FTS)	Seasonal-to-Interannual Climate Variability & Prediction	Atmospheric Circulation	Global temp. & moisture profiles
	Seasonal-to-Interannual Climate Variability & Prediction	Atmospheric Circulation	Frequent regional temp. & moisture profiles
	Long-Term Climate: Natural Variability & Change Research	Cloud Radiation Feedback	Cloud profiles & properties
	Atmospheric Chemistry & Ozone Research	Strat. & Upper Trop. Chemistry	Profiles of temp., ozone & other trace constituents
	Atmospheric Chemistry & Ozone Research	Lower Trop. Chemistry	Global distr. & total column ozone & other chemical species

Technology Products Enabling Post-2002 Missions

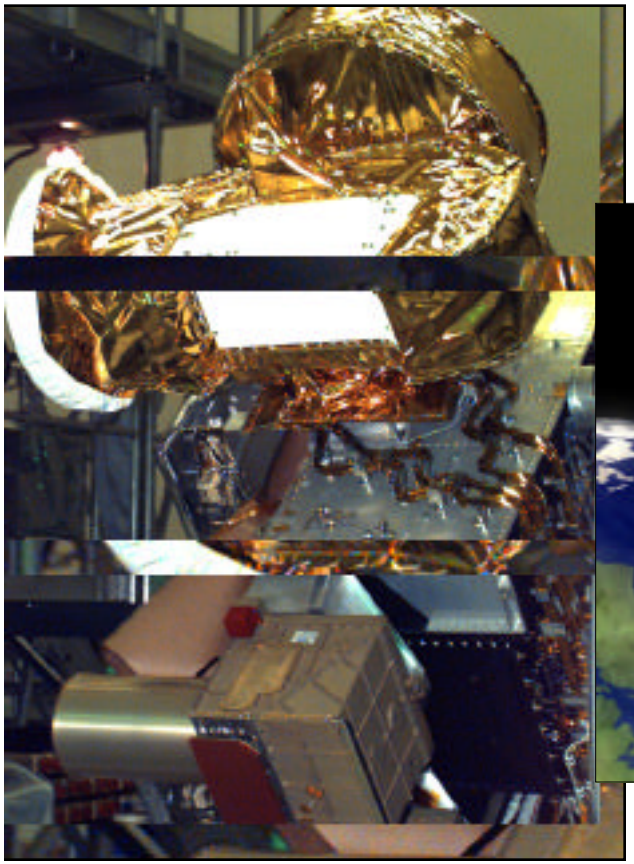
Technologies / Reference Missions[1]	Laser Transmitters & Receivers	Broadband Detectors	Fourier Transform Spectrometer	GEO – Measurement	Microwave Radiometry	GPS Surface Reflection	Submm Radiometry	Image Classification
Tropospheric Chemistry Research	✓		✓	✓				
Aerosol Radiative Forcing Research	✓	✓	✓					
Cloud Radiation Feedback Research		✓					✓	
Soil Moisture & Ocean Salinity					✓	✓		
LC/LU Inventory								✓
Tropospheric Wind Sounder	✓							

(1) References to missions from "Earth Science Enterprise (ESE) Mission Scenario for the 2002-2010 Period", Research Division, Office of Earth Science, NASA Headquarters, August 20, 1998

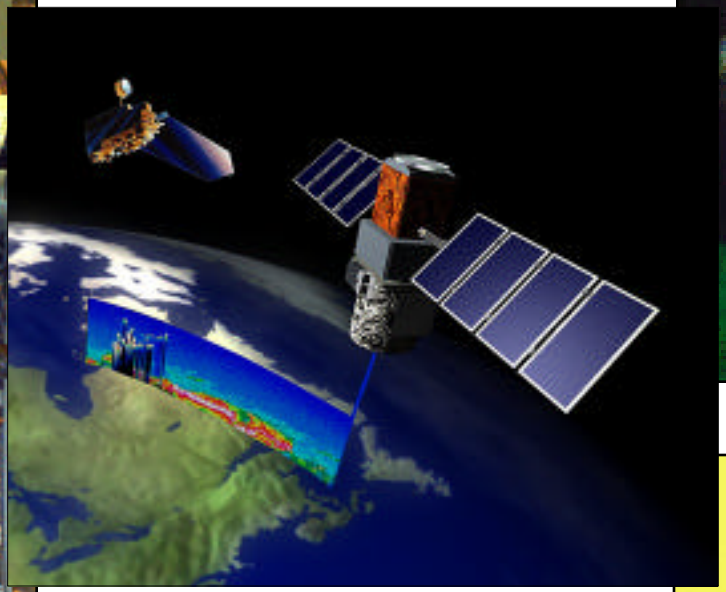
Space Technology Program Approach



Remote Sensing Product Areas

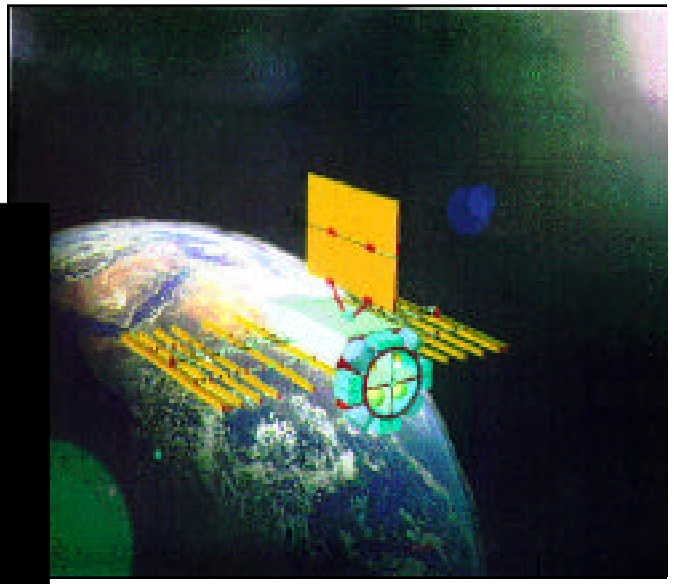


Passive Electro-Optic Sensors

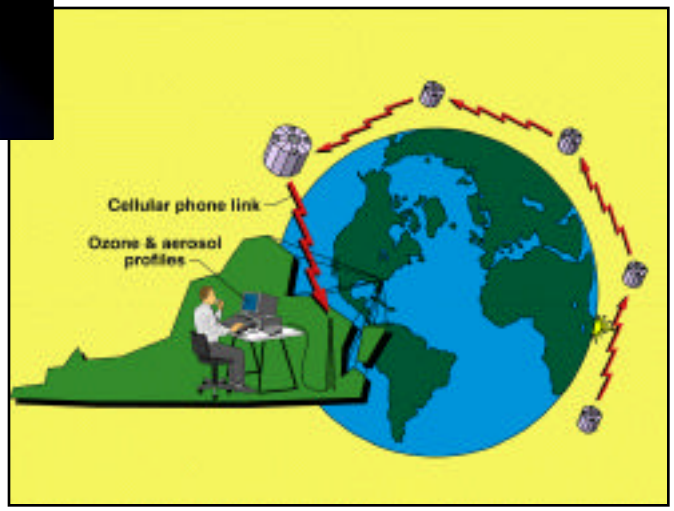


Active Optical (Lidar)

Microwave Sensors



Instrument Data Processing



Product Lines

- Advanced Lidar
  - Develop high-efficiency (>10%), high-energy (>100mJ), long-life (>10^9 shots), conductively-cooled, diode-pumped, laser transmitters over the UV to IR spectrum for advanced lidar applications.
  - Develop narrow-line optical filters (<50MHz) and high quantum efficiency (>85%) detectors.
- Passive Electro-Optic Sensors
  - Miniaturize next-generation atmospheric remote sensing instruments to realize a factor of 2-10 reduction in size, mass, and life-cycle cost.
- Microwave Sensors
  - Achieve order-of-magnitude reduction in mass of high resolution radiometers.
  - New measurement techniques: Bistatic sensing (GPS) of environmental parameters.
- Onboard Data Processing
  - Enable instrument data to be processed to EOS-Level 2 onboard the spacecraft so that timely “answers” are transmitted rather than large volumes of raw data.

FY99 Program Summary

	PIT Leader	D Hinton	S Sandford	A Little	E Kist	J Stadler	J Williams-Byrd	U Singh	J Johnson	S Sandford	S Katzberg	H Benz
	R&T Project	FTS	GAMS	GEO TROP SAT	Advanced CERES	Clouds & Aerosols LIDAR	DIAL	Winds	STAR Technology	Submillimeter LO	GPS Surface Reflection	Advanced Imaging
Product Line	Product Line Leader	Atmospheric Science Instruments						External Science & Tech				
Passive Electo-Optic Sensors	S. Sandford	X	X	X	X							
Active Optical (LIDAR)	J. Barnes					X	X	X				
Microwave Sensors	J. Johnson								X	X	X	
Instrument Data Processing	H. Benz	X	X									X
Lightweight & Multifunctional Structural Sys	S. Thibeault	X	X			X						
Breakthrough Materials	H. Maahs	X	X									
Deployable and Inflatable Structures	M. Lake					X	X					
Structural Dynamics and Geometry Control	H. Adelman	X	X									

Sensors & Detectors

Structures & Materials

FY99 Sensor & Detector Program

R&T Project	FY98 ($K)	FY99 ($K)	Comments
FTS	350	500	Complete WEB prototype
GAMS	355	0	Transitioned to IIP
GeoTropSat	150	500	Develop detector arrays for ESSP-3
FPI	295	0	Basis for NMP Proposal
Advanced CERES	395	600	Advanced detector development for EOS-II
Cloud & Aerosol Lidar	775	400	Complete NRA, 12% laser
DIAL	1250	1400	UAV aircraft infusion, ORACLE
Winds	500	850	Conduction cooled, end-pumped
STAR	925	700	Complete 1-D, focus on 2-D synthesis
Submm Local Oscillator	250	80	Non-linear crystal tech-push for ESE
GPS Surface Reflection	0	120	Co-funded by YS
Advanced Imaging	255	200	Hyperion and imaging FTS focus
TOTAL	5500	5500	

55 Civil Service FTE

FY99 Product List (partial)

Product Line	Product	Delivery
Active Optical	High Efficiency (12%) Diode Pumped ND: YLF Laser	Q4
	Hardened OZONE DIAL UV laser for aircraft infusion	Q3
	Liquid cooled diode pump for efficient end-pumping for conductively cooled Ho: Tm: YLF disk amplifiers	Q4
	Prototype blackened broadband detectors	Q2
Microwave	Generation fo 1-10mW sub-mm power using non-linear mixing approach	Q4
	Prototype 3 Level Correlator for 2D STAR concept	Q4
	L-Band Tensioned Membrane Test Article and Feasibility Analysis	Q4
	Prototype GPS delay Mapping Receiver	Q3
Passive Electo-optic	2.3 micron 1024X1024 photon noise limited FPA	Q4
	High Temperature Superconducting (HTS) Bolometric Detectors for FIR application	Q3
Instrument Data Processing	Brault Algorithm and FTS Imaging Algorithms	Q4
	DSP prototype	Q4

Sensor & Detector contributions to IIP

- Gas and Aerosol Monitoring Sensorcraft Instrument Refinement
  - Dr. Joe Zawodny, LaRC PI, in-house development
  - Miniature spectrometer development and field demonstration to measure climate drivers: ozone, aerosols, clouds, and water vapor from the mid-troposphere through the stratosphere.
  - Funding $1.56M

- Spaceborne Microwave Instrument for High Resolution remote Sensing of the Earth Surface Using a Large-Aperture Mesh Antenna (JPL)
  - Dr. Eni Njoku, JPL PI, Dr. Tom Campbell, Dr. Wes Lawrence, LaRC Co-investigators
  - LaRC responsibility: Measure the emissivity of the mesh materials at specified frequencies (L- to K-band), measure precision brightness temperatures of the mesh under on-orbit thermal gradients, and investigate design approaches to improve the mesh radiometric properties
  - LaRC Funding: $165K

Sensors and Detectors feeds NMP EO-3 Concepts

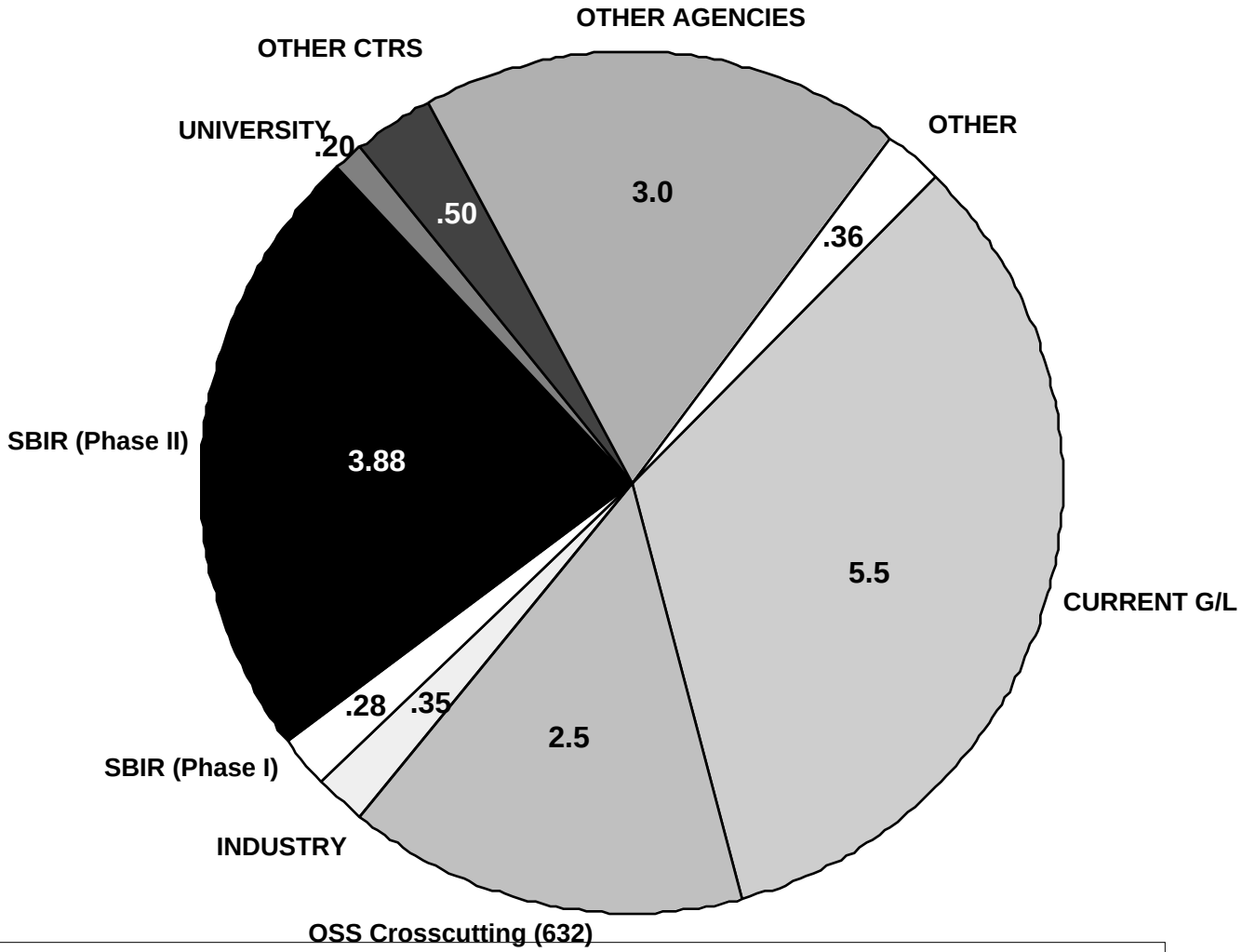
- **Geostationary Imaging Fourier Transform Spectrometer (GIFTS)**
  - Dr. Bill Smith (LaRC PI), Univ. Of Wisconsin, Space Dynamics Lab
  - Measures water vapor and wind at various layers from geostationary orbit
  - Proposed Technologies: FTS, Large area format Focal Plane detector Array (LFPA), Thermally-Stable Optical Support Structures, High-Displacement Piezoelectric Actuator (THUNDER)
- **Geostationary Tropospheric Trace Gas Imager**
  - Dr. Jack Fishman (LaRC PI), Ball Aerospace and Technologies
  - Measures trace gases (CO, NO_2, O_3) from geostationary orbit
  - Proposed Technologies: GFCR and UV Filters technique, Multifunctional structures, Large high temperature infrared 1024x1024 focal plane arrays, Flat panel radiative cooler, High precision pointing and stabilization mirrors and drives, High precision imaging filter radiometer, imaging filter spectrometer, Scientific feature extraction
- **Tropospheric Ozone Pollution sensor for Geostationary Imaging and Scientific MOnitoring (TOP-GISMO)**
  - Dr. Allen Larar (LaRC PI), Univ. of Michigan Space Physics Research Lab, Raytheon Santa Barbara Remote Sensing
  - Measures Tropospheric Ozone from geostationary orbit with applicability to other tropospheric trace gases
  - Proposed technologies: Precision control of etalon plates, Advanced active coolers, Composite optics and optical bench, Digital Signal Processor
- **CO_2 measurement using Fourier Transform Spectroscopy (CO_2-FTS)**
  - Dr. Jae Park (LaRC PI), ITT Industries Aerospace/Communication Div
  - Measures CO_2 from a high (1000 - 5000 Km) circular orbit
  - Proposed Technologies: Based on MTECH-CO2, LaRC lead for NMP IPDT, FTS, High-Displacement Piezoelectric Actuator (THUNDER), Microsensor technologies (components, materials), Composite materials for FTS structure and fore-optics

Earth Science Technology Infusion (UPN 258)
LaRC Funding Profile ($K)

	FY98	FY99	FY00
258-20 (NMP EO2)	451	300	135
258-30 (NMP EO3)	------	?	?
258-70 (Sensor & Detector Program)	5,500	5,500	?
258-80 (System Studies/IIP)*	1,060	921	883
TOTAL	7,011	6,721+?	1,018+?

*FY 98 System Studies funded from IIP budget line.

Sensors & Detectors Program offers Exceptional ROI for Earth Science Enterprise



ES Investment at LaRC Leverages $11.1M from Other Sources

Crosscutting Technology Benefits Both Earth and Space Science

Precision Deployable Reflector Technology

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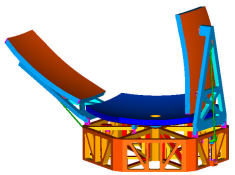
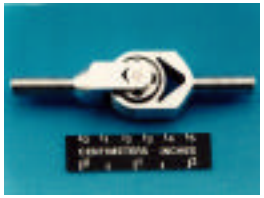
TECHNOLOGY DEVELOPMENT **MISSIONS**

Microdynamics Research

Ground Tests



Deployable Lidar Telescope
- 2.2 m aperture
- 1 micron accuracy



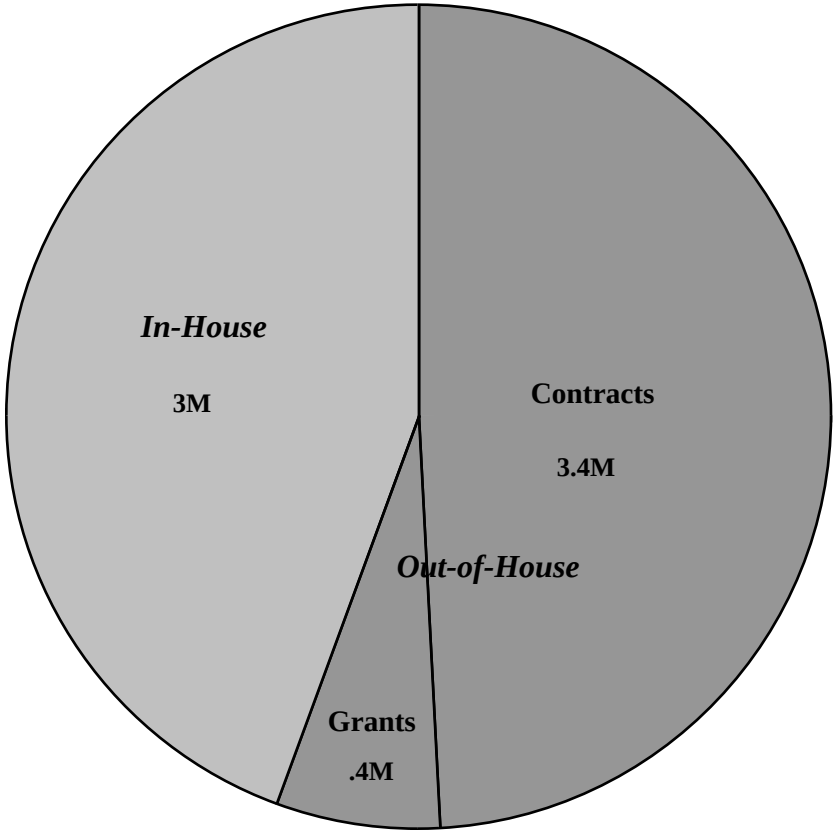
Precision Mechanism Development

Flight Tests

ORACLE Lidar

NGST
- 8 m deployable aperture
- 50 nm accuracy

Earth Science Technology Infusion (UPN 258)
Budget Allocation



Technology Enabling Future Science

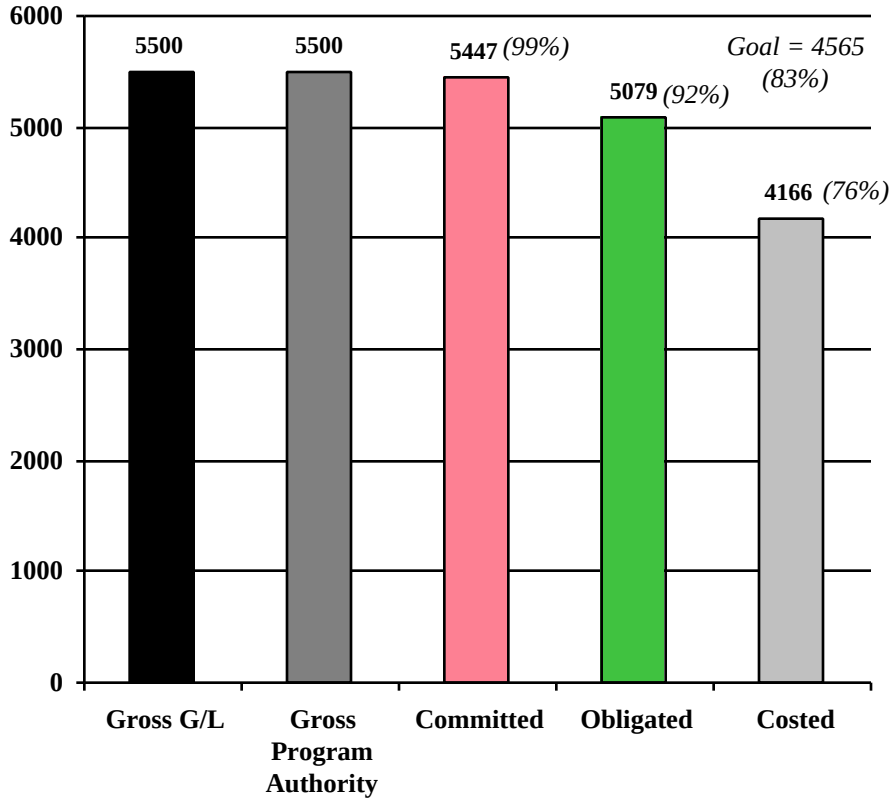
Technologies	Science Measurement	Mission
Conductively Cooled, Diode Pumped Laser Transmitter; DSP's; Rad Hard A/D	High Resolution Clouds and Aerosols Profiling	PICASSO
UV Solid State Laser Transmitter; Deployable Telescope	High Resolution Ozone Profiling	ORACLE
940 nm Solid State Laser Based Transmitter	High Resolution Water Vapor Profiling	CAPES/UAV
Miniature Spectrometer; Actuator; Onboard Processing	Stratosphere Ozone, Aerosols	GAMS
FTS Web Optical Design	Stratospheric Chemistry	SciSat-ACE
Imaging FTS; Actuators; DSP	GEO Atmosphere Sounding and Chemistry	GIFTS
FIR FTS; Optical Elements; Advanced Detectors	Cirrus Clouds and Cloud Ice Water Path	CARE/FIRSC

F.Y. 98 EOY SC&RS FUNDING STATUS
9/30/98

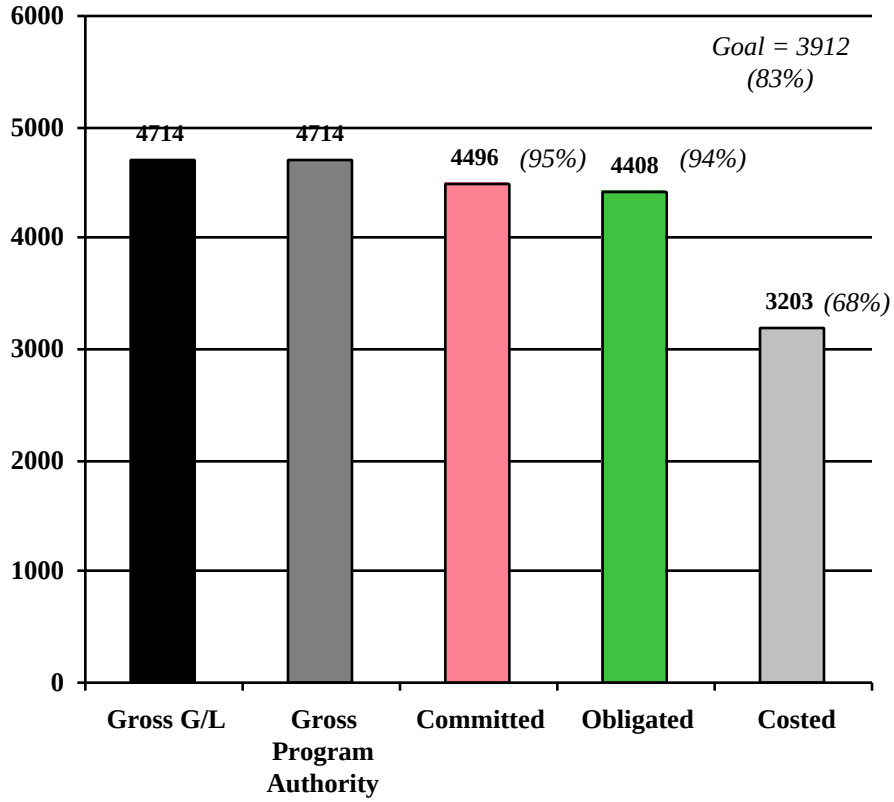
RTR	Title	Net G/L ($K)	Commits ($K)	% Comm	UnCom $	Obs ($K)	% Obs	Costs	% Costs
258-70-21-02	Advanced CERES	215	205	95%	10	93	43%	56	26%
258-70-21-03	Submillimeter LO	165	162	98%	3	160	97%	120	73%
258-70-21-06	STAR Technology	902	902	100%	0	891	99%	735	81%
258-70-21-07	WINDS	431	426	99%	5	422	98%	196	45%
258-70-21-08	DIAL	943	950	101%	-7	927	98%	767	81%
258-70-21-09	FPI Instrument Technology	160	157	98%	3	152	95%	140	88%
258-70-21-10	NRA's for Lidar Sciencecraft Tech	679	692	102%	-13	637	94%	532	78%
258-70-21-11	GAMS	363	364	100%	-1	348	96%	290	80%
258-70-21-12	Geo Trop Sat	100	100	100%	0	100	100%	14	14%
258-70-21-13	FTS	228	223	98%	5	221	97%	196	86%
258-70-21-16	SSTI Instrument Data	95	95	100%	0	95	100%	87	92%
258-70-21-17	Trade Studies	225	180	80%	45	62	28%	62	28%
258-70-21-48	Program Development	64	61	95%	3	41	64%	41	64%
258-70-21-49	Program Support	930	930	100%	0	930	100%	930	100%
	TOTAL 258	*5500*	*5447*	*99%*	*53*	*5079*	*92%*	*4166*	*76%*
632-10-13-01	Embedded Inst. Signal & Data Pr	150	0	0%	150	0	0%	0	0%
632-10-14-01	Lightweight & Multifunctional St	566	547	97%	19	512	90%	227	40%
632-10-14-02	Breakthrough Materials	348	341	98%	7	337	97%	229	66%
632-10-14-03	Deployable and Inflatable Struc	687	687	100%	0	680	99%	484	70%
632-10-14-04	Structural Dynamics and Geometr	397	388	98%	9	380	96%	217	55%
632-10-14-05	Next Gen Design & Analysis Tools	691	689	100%	2	658	95%	548	79%
632-10-14-06	Inflatables	50	32	64%	18	32	64%	0	0%
632-10-14-25	Program Development	318	314	99%	4	314	99%	51	16%
632-20-21-13	FTS S&M Tech.	170	161	95%	9	158	93%	110	65%
632-10-14-49	Program Support	1337	1337	100%	0	1337	100%	1337	100%
	TOTAL 632	*4714*	*4496*	*95%*	*218*	*4408*	*94%*	*3203*	*68%*
	TOTAL	**10214**	**9943**	**97%**	**271**	**9487**	**93%**	**7369**	**72%**

F.Y. 98 SC&RS Gross Cost & Obligation Status 9/30/98

Code Y Funds (UPN 258)



Code S Funds (UPN 632)



Recent Accomplishments

- Gas and Aerosol Monitoring Sensorcraft (GAMS) team successfully completed field experiments at the Mauna Loa Observatory to collect the critical data required for radiometric calibration/validation of the spectrometer and development/validation of the science algorithms. Evaluation of the data indicates the spectrometer's performance meets or exceeds expectations.
- STAR imaging tests completed. Tests confirm that modeling capability developed under the technology program can be used to estimate on-orbit calibration errors in thinned arrays.
- Broadband detector NRA developed, released, and evaluated. Contract negotiations are currently being awarded
- Application of LO systems and devices in telecommunication industry received. Negotiation for MOA license agreement with industry partner for patented Submm technology underway w/potential for >$10M royalties to NASA in 1999 alone.
- With support of Code YS, developed and demonstrated optics technology and Far-IR technique for the measurement of cirrus clouds and cloud ice water path. Far-IR Sensor for Cirrus (FIRSC) was aircraft flight validated in May.
- PICASSO-CENA prototype 1-micron laser has been developed and delivered. Life testing has been initiated (3B shots required).
- LaRC laser technologists successfully developed and demonstrated the SPARCLE breadboard 2-micron laser transmitter. The breadboard, delivered 2 months ahead of schedule, generates 130 milliJoules output energy @ 6 Hz and meets or exceeds all SPARCLE design requirements.

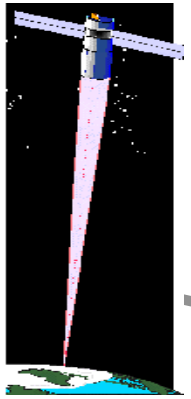
LIDAR Instrument Roadmap

1998 → 2020

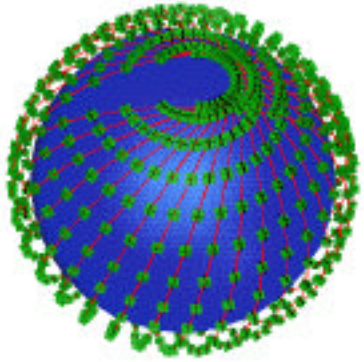
Shuttle Based Lidar Mission

Autonomous Ground /Aircraft Operation

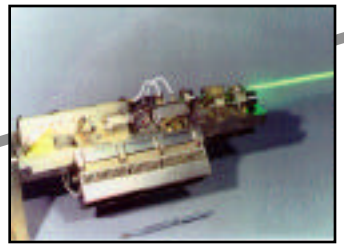
Free Flyer Demonstration



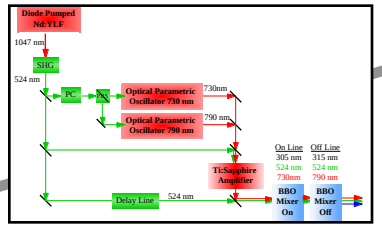
NPOESS Operational System



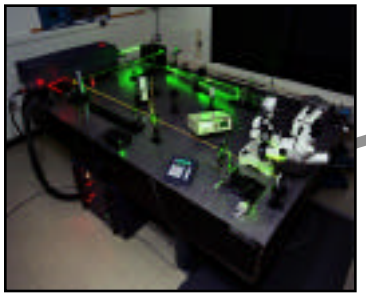
Global-monitoring LIDAR System



Space Packaging



Hi-efficiency Transmitter Design and Development

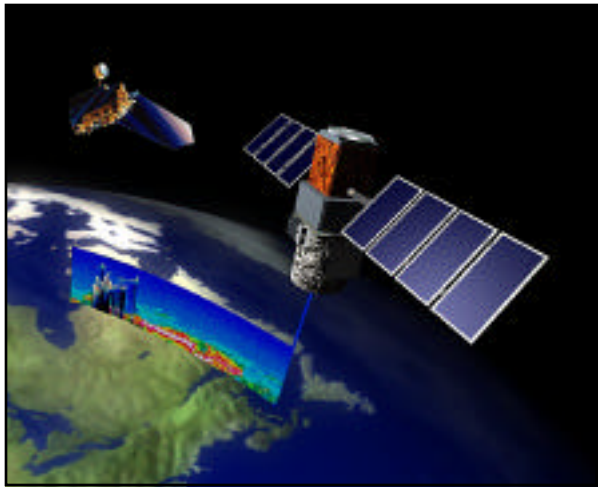


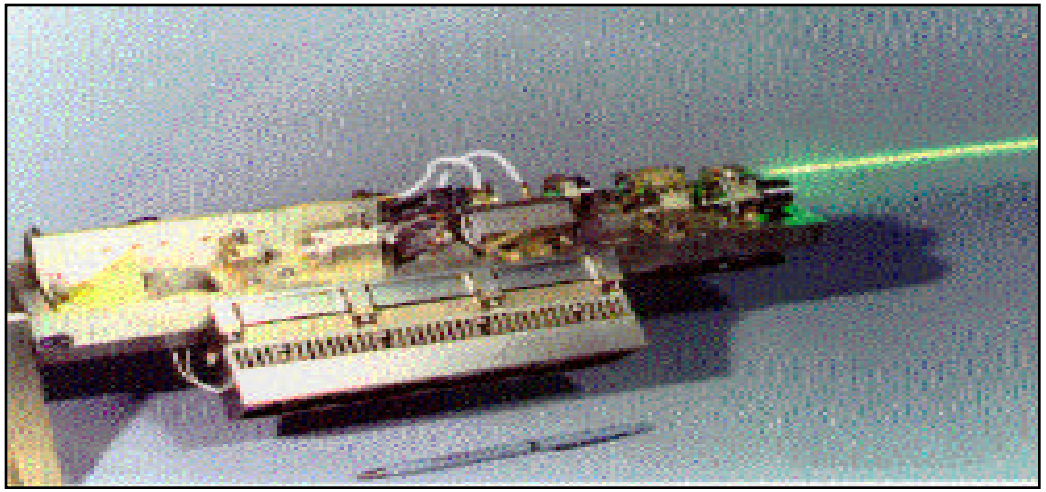
Laboratory demonstration

ESTO

Earth Science Technology Office

Cloud and Aerosol Lidar Transmitter





PICASSO-CENA prototype 1-micron laser has been developed and delivered. Life testing has been initiated (3B shots required).

Summary

- Science, milestone and metric-driven core technology program
- Component and pre-prototype development in response to system-level requirements
- Focus on reduced cost, enhanced capability, new science for next generation (EOS-II, ESSP) of instruments and advanced measurement techniques
- Scientists, engineers, and technologists working together to enable ES vision for low-cost, highly-capable science missions
- LaRC Core Technology Program is good value for Earth Science Enterprise.
  - Good ROI for Earth Science: small investment for large return
  - Highly leveraged: every dollar invested has $3 of buying power
- Robust technology program is essential to LaRC role as Collaborating Center for Atmospheric Science

- Powerpoint slides are available at
  - ftp:spacetech.larc.nasa.gov/

Supporting Information

- Product Line Leaders
- Traceability of Technology Products to CAN
- Mapping Technology Products to Post-2002 Missions
- Technology Strategy Goals & Metrics

Product Line Leaders

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Traceability of Technology Products to CNA

Science Theme/Earth System Quantity	Technology Products	Technology Thrust Area
Seasonal-to-Interannual Climate Variability Soil Moisture Long-Term Climate Sea Surface Salinity	Low-mass Deployable Antenna L-, S- and C-band; H, V polarization	**Advanced Microwave Radiometry**
Atmospheric Chemistry and O_3 – Stratospheric & Upper Tropospheric Chemistry Profiles of OH and cirrus clouds	Sub-mm heterodyne spectrometer Sub-mm local oscillator: 1-10mW tunable over sub-mm range (2.5THz for OH)	**Submillimeter Sensing Technology**

Traceability of Technology Products to CNA

Science Theme/Earth System Quantity	Technology Products	Technology Thrust Area
Tropospheric winds Atmospheric Chemistry and O_3 – Strat & Upper Trop Chemistry Profiles of temp, O_3, and other trace constituents (ClO, NO2, HCl, HF, CFCs) Long-Term Climate – Radiative forcing Atmospheric aerosol profiles	2-micron laser transmitter for Coherent Doppler Wind Lidar (CDWL) High WPE, long-life, lightweight DIAL Laser Diode life testing PMT & APD detectors Advanced on-board data processing	**Lidar Technologies**
Long-Term Climate Cloud Radiation Feedback – Broadband Earth radiation budget	Spectrally-flat, ultra-sensitive radiation sensors	**Broadband Radiometer Technologies**

Traceability of Technology Products to CNA

Science Theme/Earth System Quantity	Technology Products	Technology Thrust Area
Atm Chem and O_3 – Strat & Upper Trop Chemistry Profiles of temp, O_3, and other trace constituents (ClO, NO_2, HCl, HF, CFCs) Atm Chem and O_3 – Lower Trop Chemistry Global distribution & total column of O_3 and others	1024x1024 photon noise limited FPA	**Geo Technologies**
Atm Chem and O_3 – Strat & Upper Trop Chemistry Profiles of temp, O_3, and other trace constituents (ClO, NO_2, HCl, HF, CFCs) SI Climate – Atm Circulation Global temperature & moisture profiles	On-board data processing Advanced efficient actuator Lightweight optics Diffraction gratings Metrology lasers	**FTS Technologies**

Traceability of Technology Products to CNA

Science Theme/Earth System Quantity	Technology Products	Technology Thrust Area
Land Cover/Land Use High spatial resolution mapping	Information-adaptive processing to classify and code Hyperspectral data	**Adaptive Image Classification**
SI Climate Vector surface winds Sea-State Long-Term Climate Ocean surface salinity Land Use/Land Cover Wetlands mapping	GPS reflection technologies – low cost, low mass receivers	**GPS Technologies**

Mapping Technology Products to Post-2002 Missions

Technology Development Task	Relevant Mission[1]	Science Priority[2]
2Winds Lidar	OP-2: Tropospheric Wind Sounder OP-4: Advanced Geostationary Sounder	3 by Hydrology and Mesoscale Weather Panel
Clouds & Aerosol Lidar	EX-1: Tropospheric Chemistry Research Mission(s) EX-2: Aerosol Radiative Forcing Research Mission	2 by Atm. Chemistry Panel 1 by Atm. Climate Physics Panel
O_3 DIAL	EX-1: Tropospheric Chemistry Research Mission(s)	2 by Atm. Chemistry Panel
Water Vapor DIAL	EX-2: Aerosol Radiative Forcing Research Mission	1 by Atm. Climate Physics Panel

(1) References to missions from "Earth Science Enterprise (ESE) Mission Scenario for the 2002-2010 Period", Research Division, Office of Earth Science, NASA Headquarters, August 20, 1998

(2) References to priorities from "Summary of Discipline Panel Reviews of the Request for Information (RFI) Responses Concerning Mission Concepts in the Post-2002 Era", Research Division, Office of Earth Science, NASA Headquarters, August 5, 1998

Mapping Technology Products to Post-2002 Missions

Technology Development Task	Relevant Mission[1]	Science Priority[2]
Earth Radiation Budget Technologies	EX-2: Aerosol Radiative Forcing Research Mission EX-3: Cloud-Radiation Feedback Research Mission EOS-2: Climate Variability and Trend Mission	1 by Atm. Climate Panel 2 by Atm. Climate Panel 3 by Atm. Climate Panel
Submm LO	EX-3: Cloud-Radiation Feedback Research Mission	2 by Atm. Climate Panel
STAR	EX-4: Soil Moisture and Ocean Salinity Observing Mission	2 by Hydrology & Mesoscale Weather Panel

(1) References to missions from "Earth Science Enterprise (ESE) Mission Scenario for the 2002-2010 Period", Research Division, Office of Earth Science, NASA Headquarters, August 20, 1998

(2) References to priorities from "Summary of Discipline Panel Reviews of the Request for Information (RFI) Responses Concerning Mission Concepts in the Post-2002 Era", Research Division, Office of Earth Science, NASA Headquarters, August 5, 1998

Mapping Technology Products to Post-2002 Missions

Technology Development Task	Relevant Mission[1]	Science Priority[2]
GEO TropSat	EX-1: Tropospheric Chemistry Research Mission(s)	2 by Atm. Chemistry Panel
FTS Technologies	EX-1: Tropospheric Chemistry Research Mission(s) EX-2: Aerosol Radiative Forcing Research Mission	2 by Atm. Chemistry Panel 1 by Atm. Climate Physics Panel
GPS Surface Reflection	EX-4: Soil Moisture and Ocean Salinity Observing Mission EOS-5: Ocean Surface Wind Measurement Program	2 by Hydrology & Mesoscale Panel 1 by Ocean & Ice Panel
Adaptive Image Classification	EOS-1: Land Cover/Land Use Inventory Program OP-6: Special Event Imager	1 by LC/LU Panel 3 by Solid Earth Panel

(1) References to missions from "Earth Science Enterprise (ESE) Mission Scenario for the 2002-2010 Period", Research Division, Office of Earth Science, NASA Headquarters, August 20, 1998

(2) References to priorities from "Summary of Discipline Panel Reviews of the Request for Information (RFI) Responses Concerning Mission Concepts in the Post-2002 Era", Research Division, Office of Earth Science, NASA Headquarters, August 5, 1998

Technology Strategy Goals & Metrics

(1) Maintain a traceable link between science objectives and technology.

Supporting Metrics:

1) Annual ratification of the ESTP Needs Database by OES and the Technology Subcommittee (TSC) of the Earth System Science and Applications Advisory Committee (ESSAAC).

Status:

LaRC PI's and technologists participate in CNA updates.

Technology Strategy Goals & Metrics

(2) Ensure overall program cost-effectiveness through technology advances and application.

Supporting Metrics:

1) At least twenty-five (25) percent of funded development tasks advance by at least one technology readiness levels (TRL) each year.

Status:

Broadband ERB detectors from TRL 2,3 to TRL 6 in 15 months.

CAL products from TRL2, 3, 4 to TRL 6 in 15 months.

2) Annually transfer at least one (1) technology development to a commercial entity or into operational use.

Status:

GAMS transitioned to IIP.

3) Biennial enabling of at least one (1) new science measurement capability via a technology-push development.

Status:

GPS Surface reflection new technique for SSS, Ocean Winds and Wetlands mapping

Technology Strategy Goals & Metrics

(3) Ensure the program supports three-year acquisition timelines for flight and ground systems.

Supporting Metrics:

1) At least fifty (50) percent of near-term technologies have a 2 to 3 year-to-launch horizon.

Status:

Broadband ERB detectors ready for infusion within 15 months.

(4) Ensure that program considers near, mid and far term horizons.

Supporting Metrics:

1) Technology funding allocated at 60% for near, 25% for mid and 15% for far term research.

Status:

(5) Leverage technology investments through cross-Enterprise program synergy and external partnerships.

Supporting Metrics:

1) **Annually establish at least one joint agreement within another NASA program that results in the inclusion of at least two (2) ESE requirements**

   Status:

   CAL and FTS leverage CETDP (632)

2) **Annually establish at least one joint agreement with a program external from NASA that results in the inclusion of at least one (1) ESE requirement**

   Status:

   Tropospheric winds requirement in IPO IORD (2 micron winds Lidar)